We Claim:

1. A rolling apparatus for rolling a workpiece rotatable about a rotational axis, the rolling apparatus comprising:

a rolling arm;

an arm support for supporting the rolling arm to allow the arm to follow the workpiece as it rotates for being rolled;

a first rolling head mounted on the rolling arm to engage the workpiece and apply pressure thereto during a rolling operation;

a second rolling head mounted on the rolling arm spaced from the first rolling head to engage the workpiece and to apply pressure thereto during a rolling operation; and

a drive associated with the rolling arm for shifting the first and second rolling heads relative to one another between an open position to provide clearance between the heads for the bearing to be rolled and a closed position for undertaking the rolling operation.

2. The rolling apparatus of Claim 1 wherein the first rolling head is fixed to the rolling arm and the second rolling head is movable rectilinearly along the rolling arm between the open position and the closed position.

3. The rolling apparatus of Claim 2 wherein slide surfaces on the second rolling head and the rolling arm are engaged to guide the second rolling head for rectilinear sliding movement along the rolling arm.

4. The rolling apparatus of Claim 2 wherein the drive associated with the rolling arm comprises a fluid cylinder mounted on the rolling arm and connected to the second rolling head to shift the second rolling head rectilinearly along the rolling arm.

5. The rolling apparatus of Claim 1 wherein the drive associated with the rolling arm comprises a motor drive mounted on the rolling arm and

connected to at least the second rolling head to shift it between the open and closed positions.

6. The rolling apparatus of Claim 1 wherein:

the first rolling head is fixed on the rolling arm;

guide surfaces on the rolling arm and the second rolling head that guide the second rolling head for movement toward and from the first rolling head; and

the drive is mounted on the rolling arm for shifting the second rolling head toward or away from the first rolling head.

7. The rolling apparatus of Claim 6 wherein the drive is a hydraulic cylinder device having one portion fixed to the rolling arm and a second movable portion fixed to the second rolling head to move the second rolling head.

8. The rolling apparatus of Claim 1 wherein the arm support comprises a lever having spaced ends with one end pivotally connected to the rolling arm for pivoting of the rolling arm in one direction, and

an axial shift assembly to which the other end of the arm is pivotally connected for pivoting of the lever arm in another direction.

9. The rolling apparatus of Claim 1 wherein the first and second rolling heads are at one end of the rolling arm;

a counterweight is mounted on an opposite end of the rolling arm to counterbalance the arm.

10. The rolling apparatus of Claim 9 wherein the arm support comprises a pivoted lever which is pivotally connected to the rolling arm between the rolling heads and the counterweight.

11. The rolling apparatus of Claim 1 wherein the rolling arm is elongated horizontally;

a portion on the rolling arm is positioned behind the first rolling head to resist the forces applied during the rolling operation.

12. The rolling apparatus of Claim 11 wherein:

the drive comprises a hydraulic cylinder having a portion thereof shifting the second roller drive to the closed position; and

a portion of the arm is positioned behind the hydraulic cylinder to resist the forces applied during the rolling operation.

13. A crankshaft rolling apparatus that allows roll hardening of closely spaced bearings of crankshafts in a single rolling operation, the crankshaft rolling apparatus comprising:

a crankshaft rotary support device including a motor for rotating the crankshaft about an axis thereof;

a plurality of arms having a narrow configuration in a widthwise dimension thereof generally extending along the crankshaft axis and being elongated in a lengthwise dimension thereof transverse to the crankshaft axis, the arms carrying rolling tools for rolling the crankshaft bearings;

a plurality of pivotal support structures each pivotally mounting one of the arms for allowing the arms to roll bearings eccentrically oriented relative to the crankshaft axis;

a single narrow drive cylinder assembly on each of the narrow arms for shifting the rolling tools into clamping engagement with the bearings with a predetermined variable and high clamping force for roll hardening of the crankshaft bearings; and

a plurality of small force generating cylinders of each of the drive cylinder assemblies that cooperate to generate the predetermined variable and high clamping force thereof and which are aligned with each other so as not to increase the narrow arm width allowing the arms to be closely

positioned one next to the other for simultaneous rolling of closely spaced crankshaft bearings.

14. The crankshaft rolling apparatus of claim 13 wherein the width of the drive cylinder assembly is less than approximately twenty-four millimeters (mm), and the predetermined variable and high clamping force generated via the small force generating cylinders thereof includes forces of approximately twenty kilonewtons (KN) at a source pressure of 138 bar.

15. The crankshaft rolling apparatus of claim 13 wherein the support structures each include a lateral shift mechanism to allow the arms to be shifted axially for rolling of different configurations of crankshafts with varied spacings of bearings.

16. The crankshaft rolling apparatus of claim 13 wherein the support structures of the narrow arms and the drive cylinder assemblies on the narrow arms are all disposed on one side of the crankshaft axis, and the drive cylinder assemblies of the arms that roll the crankshaft bearings are substantially aligned with each other in a direction parallel to the crankshaft axis on the one side of the axis.

17. The crankshaft rolling apparatus of claim 13 wherein the arms each mount a back-up rolling tool and a force-applying rolling tool so that only one arm is needed for rolling each crankshaft bearing.

18. The crankshaft rolling apparatus of claim 17 wherein the arm includes bearing ways for sliding movement of the force-applying tool, and the drive cylinder assembly advances and retracts the force-applying tool linearly along the arm bearing ways so that the clamping force of the cylinder assembly is applied directly to the bearing in a radial direction with respect thereto.

19. The crankshaft rolling apparatus of claim 13 wherein the force generating cylinders each include a piston rod actuated to be advanced and retracted by selective application of power fluid to the force generating cylinders, and

a common elongate drive bar fixed to each of the piston rods of a drive cylinder assembly to keep the piston rods advancing and retracting at the same rate upon actuation thereof.

20. The crankshaft rolling apparatus of claim 13 wherein the drive cylinder assembly is fixedly mounted on the rolling arm so that the drive cylinder assembly does not pivot upon actuation thereof.

21. The crankshaft rolling apparatus of claim 13 wherein the support structures each include a hanger member pivotally attached to one of the arms and extending generally vertically with the arm extending generally horizontally and the aligned force generating cylinders being vertically oriented one over the other.

22. The crankshaft rolling apparatus of claim 21 wherein the hanger members each have opposite upper and lower ends with the lower ends pivotally attached to the respective arms,

hanger support members of the pivotal support structures to which the upper ends of the hanger members are pivotally attached, and

an upper cross bridge mounting the hanger support members for lateral shifting to allow the arms to roll crankshafts with differing bearing spacings.

23. The crankshaft rolling apparatus of claim 13 wherein the rolling arms each include forward and rearward ends with the arms pivotally attached to respective ones of the pivotal support structures intermediate the

ends thereof and the rolling tools being mounted to the arms toward the forward end thereof, and

a counterweight at the rearward end of each of the arms to counter the weight of the arms forwardly of the pivot attachment including the tools thereon so that the arms are substantially mass balanced with effects of the arm mass minimized during the rolling operation.

24. The crankshaft rolling apparatus of claim 13 wherein the arms include a strain sensor mounted thereto that detects structural deflection of the arms for generating a signal representative of a measured amount of the structural deflection of the arm, and

circuitry connected to strain sensor calibrated to determine force generated on the bearings by the tools based on the signal received from the sensor.

25. The crankshaft rolling apparatus of claim 13 wherein the rolling arms each include a coupling portion, and

an arm positioner having carriage assemblies removably mounted thereto with each carriage assembly including a plurality of coupling portions at predetermined positions corresponding to a predetermined crankshaft configuration with the carriage assembly coupling portions to be engaged with the coupling portions of respective ones of the arms to orient the arms for clamping onto and rolling of the crankshaft bearings of the predetermined crankshaft configuration.

26. A crankshaft rolling apparatus for rolling crankshafts having an elongate axis with main bearings centered on the axis and pin bearings offset therefrom, the crankshaft rolling apparatus comprising:

a frame;

a rotary drive device mounted to the frame that supports and rotates a crankshaft about the axis thereof;

a plurality of rolling arms including rolling tools that can be shifted relative to each other between an open position and a closed position for clamping onto the crankshaft bearings;

pivotal supports pivotally attached to the rolling arms to allow the clamped rolling tools to follow the rotary motion of the bearings and roll harden the bearings; and

an arm positioner mounted to the frame and carrying one of a plurality of arm phasing assemblies each tailored to different crankshaft configurations, the arm positioner being movable relative to the frame for orienting the arms so that the open tools thereof can be clamped onto the bearings of the crankshaft supported by the rotary drive device in a predetermined rotary position thereof.

27. The crankshaft rolling apparatus of claim 26 wherein the rolling arms include a lowered position prior to rolling of the crankshaft and a raised position for rolling of the crankshaft, and the arm positioner includes shift assemblies for lowering and raising the arm phasing assembly to shift the arms between the lowered and raised positions thereof.

28. The crankshaft rolling apparatus of claim 27 wherein the arms have spaced ends with the tooling at one end of each of the arms and the arm positioner adjacent thereto and the pivotal supports pivotally attached to the arms intermediate the ends thereof, and

counterweights at the other end of each of the arms weighted to optimize the weight at the forward ends of the arms for lifting thereof and for allowing the arms to be rapidly shifted from the upper positions to the lower positions via the arm positioner.

29. The crankshaft rolling apparatus of claim 26 wherein the arm phasing assemblies each include a plurality of positioning members oriented to correspond to the orientation of the crankshaft bearings of a particular crankshaft with the crankshaft in the predetermined rotary position thereof, and the positioning members and the arms including respective coupling portions that are engaged for shifting of the arms by the positioning members to allow the open arm tools to clamp onto the crankshaft bearings.

30. The crankshaft rolling apparatus of claim 29 wherein the arm positioner includes a slide to which the positioning members are detachably mounted to change the crankshaft configuration for which the arm phasing assembly is tailored.

31. The crankshaft rolling apparatus of claim 29 wherein the rotary drive device includes end supports for holding and supporting opposite ends of the crankshaft for rotation, and the arm positioner includes at least one positioning member that keeps one of the arms having the tools thereof clamped onto a main bearing of the crankshaft substantially stationary to provide an intermediate support to the crankshaft between the ends thereof during a rolling operation.

32. The crankshaft rolling apparatus of claim 26 wherein the arms have a narrow configuration to allow all of the arms to be positioned side-by-side for simultaneous rolling of closely spaced bearings and all of the pivotal supports are mounted on one side of the crankshaft axis rearwardly on the frame, and the arm positioner is mounted on the other side of the crankshaft axis forwardly on the frame.

33. The crankshaft rolling apparatus of claim 32 including narrow power cylinders mounted to the arms with the cylinders positioned side-by-side on the one side of the crankshaft axis.

34. A method for roll hardening a rotatable workpiece having a rotational axis, the method comprising:

loading the workpiece into a rotational drive apparatus adapted to hold and to rotate the workpiece about its rotational axis;

providing a plurality of rolling arms;

providing at least a first rolling head and a second rolling head on each of the rolling arms;

shifting the first and second rolling heads relative to one another and closer together to clamp on the workpiece by a drive associated with the rolling arm; and

rotating the workpiece and pivoting the rolling arms so that the arms are free to follow the workpiece engaged by the rolling heads thereon for roll hardening of the workpiece by the rolling heads.

35. A method in accordance with Claim 34 wherein the first and second rolling heads comprise a clamping jaw on each rolling arm, and further comprising moving the second rolling head along a guide surface on the rolling arm toward the first rolling head by fluid pressure.

36. A method in accordance with Claim 35 comprising:

providing a fluid cylinder device on each rolling arm; and

moving the second rolling head in a first direction on the rolling arm to clamp the workpiece by the actuation of the fluid cylinder device and moving the second rolling head in an opposite direction on the rolling arm to the first direction to release the workpiece for removal.

37. A method in accordance with Claim 34 comprising:

fixedly mounting the first rolling head on each of the rolling arms; and

shifting each of the second rolling heads rectilinearly along its supporting rolling arm to clamp the workpiece.

38. A method in accordance with Claim 34 comprising pivotally supporting each rolling arm to allow the arms to follow the rotary movement of the workpiece.

39. A method in accordance with Claim 34 comprising:

pivotally supporting the rolling arms at a pivot location to allow the arms to follow the workpiece during rotation thereof; and

applying a counterweight force to one end of the arms to offset the rolling heads located at the other end of the arms with the pivot location therebetween.

40. A method in accordance with claim 34 wherein the workpiece is a crankshaft having an elongate axis with main bearings centered on the axis and pin bearings offset therefrom,

setting a predetermined rotary position for the crankshaft held by the rotational drive apparatus with the crankshaft bearings at predetermined positions, and

shifting at least all of the arms for rolling of the pin bearings in unison to predetermined positions coordinated with the predetermined positions of the pin bearings to allow the rolling heads thereon to be shifted and clamped onto the pin bearings.

41. A method for roll hardening a plurality of differently configured crankshafts each having an axis of rotation and main bearings centered on the axis and pin bearings offset therefrom, the method comprising:

positioning one of the crankshafts having a particular configuration at a predetermined rotary position as held in a rotary drive and

support device with the pin bearings at predetermined positions about the crankshaft axis and spaced therefrom in fore and aft and vertical up and down directions;

providing pivotally mounted rolling arms having tools that shift from an open position to a closed position clamped onto the bearings for roll hardening thereof;

selecting an arm phasing assembly from one of a plurality of different arm phasing assemblies that are each tailored to different crankshaft configurations with the arm phasing assembly selected based on the configuration of the crankshaft to be rolled;

shifting at least the rolling arms for the pin bearings from inoperative positions to predetermined operative positions by engagement with the selected arm phasing assembly with the predetermined arm operative positions being coordinated with the predetermined positions of the pin bearings to allow the tools to shift from their open to closed positions for clamping onto the pin bearings;

shifting the tools from the open positions to the closed positions thereof clamping the tools onto the crankshaft bearings;

shifting the arm phasing assembly into a clearance position relative to the rotating crankshaft leaving the arms clamped to the bearings via the tools thereof; and

rotating the crankshaft about the axis thereof by the rotary drive and support device with the pivotal arms following the rotation of the crankshaft and roll hardening the crankshaft by way of the tools clamped thereon.

42. The method of claim 41 wherein each of the arms has a pair of clamping tools thereon forming a clamping jaw open upwardly with the tools in the open positions thereof, and the pin bearing arms are shifted from the inoperative positions to the predetermined operative positions thereof by lifting the arms from lowered positions where the arms are located for

crankshaft loading/unloading operations to raised positions with the tools of the open clamping jaw of the arms on either side of the pin bearings.

43. The method of claim 41 including stopping rotation of the crankshaft at the predetermined rotary position after a rolling operation, shifting the tools from the closed positions to the open positions thereof, shifting the arm phasing assembly from the clearance position into engagement with the arms that are in the predetermined operative position thereof, shifting the arm phasing assembling along with the pin bearing arms back to the clearance position, and unloading the rolled crankshaft from the rotary drive and support device and loading another crankshaft for being rolled into the device.

44. The method of claim 43 wherein the arm phasing assembly is shifted from the clearance position into engagement with the arms by raising the arm phasing assembly.

45. The method of claim 41 including removably mounting the selected arm phasing assembly to an arm positioner that shifts the arm phasing assembly into and out from engagement with the pin bearing arms.

46. The method of claim 45 wherein the arm positioner shifts the arm phasing assembly into engagement with the pin bearing arms by raising and pivoting the assembly into engagement with the pin bearing arms, and the arm positioner shifts the arm phasing assembly out of engagement with the pin bearing arms by pivoting and lowering the arm phasing assembly to the clearance position thereof.

47. The method of claim 41 wherein each of the arms has a pair of tools thereon for clamping onto a crankshaft bearing, and

keeping at least one of the arms used for rolling the main bearings fixed with the tools thereof clamped onto the main bearing to support the crankshaft intermediate the ends thereof against deflecting during a rolling operation.

48. The method of claim 41 including:

unloading one crankshaft after roll hardening thereof and loading another crankshaft of a different configuration form the one roll hardened crankshaft for being held by the rotary drive and support device at a predetermined rotary position thereof;

changing the arm phasing assembly to another selected arm phasing assembly tailored to the configuration of the crankshaft to be rolled; and

adjusting the arms in a direction substantially parallel to the crankshaft axis to align the arms with the bearing arm is to roll.

49. A method of detecting applied forces to a crankshaft in a rolling operation thereof, the method comprising:

mounting a strain sensor to a rolling arm having at least one rolling tool;

clamping a bearing of the crankshaft with the at least one rolling tool and another rolling tool;

detecting structural deflection of the arm with the strain sensor due to the clamping of the bearing as the crankshaft is rolled; and

identifying clamping force levels on the clamped bearing based on the amount of arm deflection detected by the strain sensor.

50. An apparatus for detecting applied force to a crankshaft in a rolling operation, the apparatus comprising:

a rolling arm;

a rolling tool mounted to the arm for being clamped onto a bearing of the crankshaft; and

a strain sensor mounted to the arm to detect structural deflection thereof with the tool clamped onto the bearing, the strain sensor generating a signal based on the amount of arm deflection representative of the clamping force being applied to the bearing during a crankshaft rolling operation.